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Field Evaluation of a Constant-Rate Herbicide Sprayer for ATVs and UTVs

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April 2008
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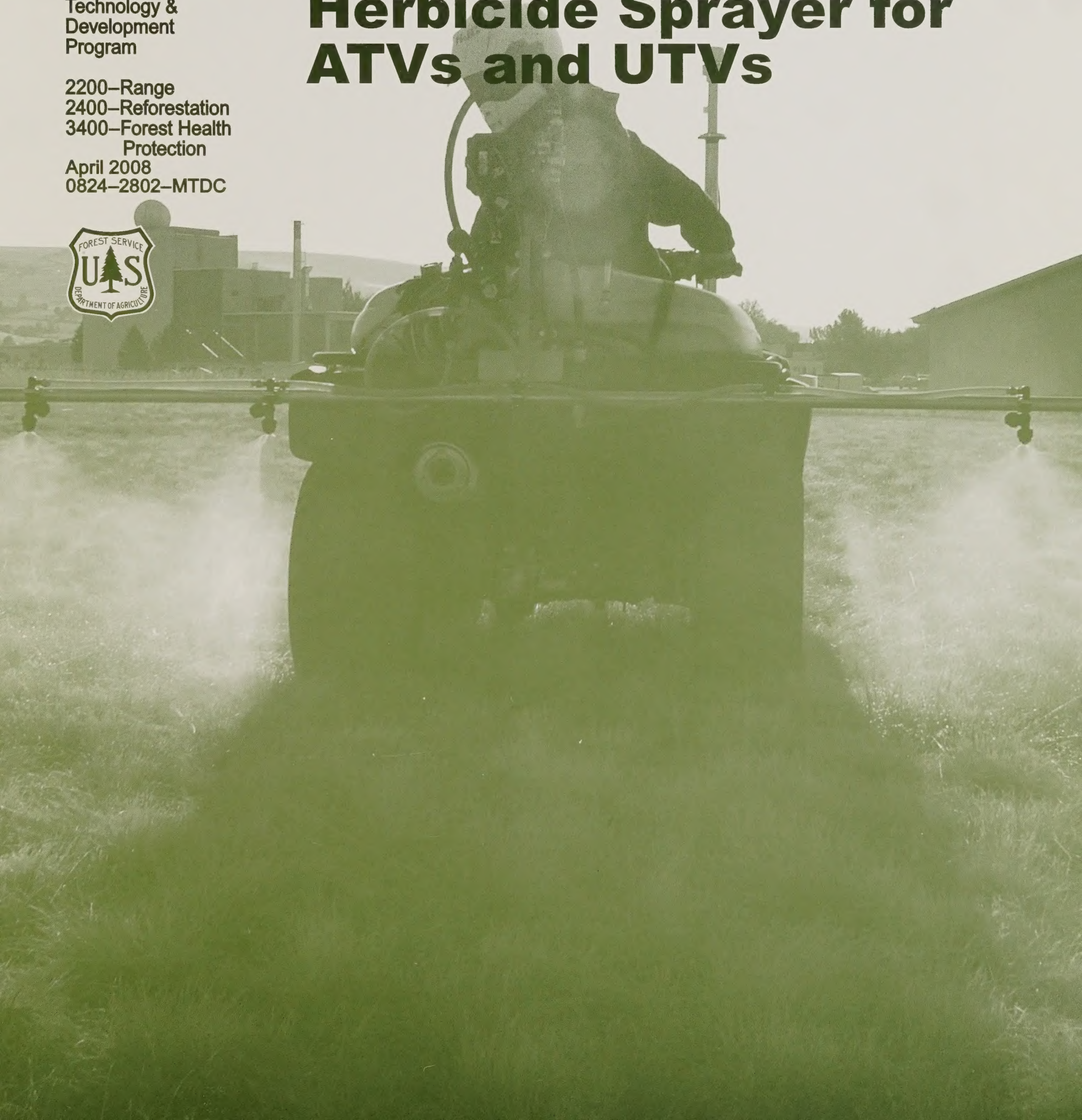
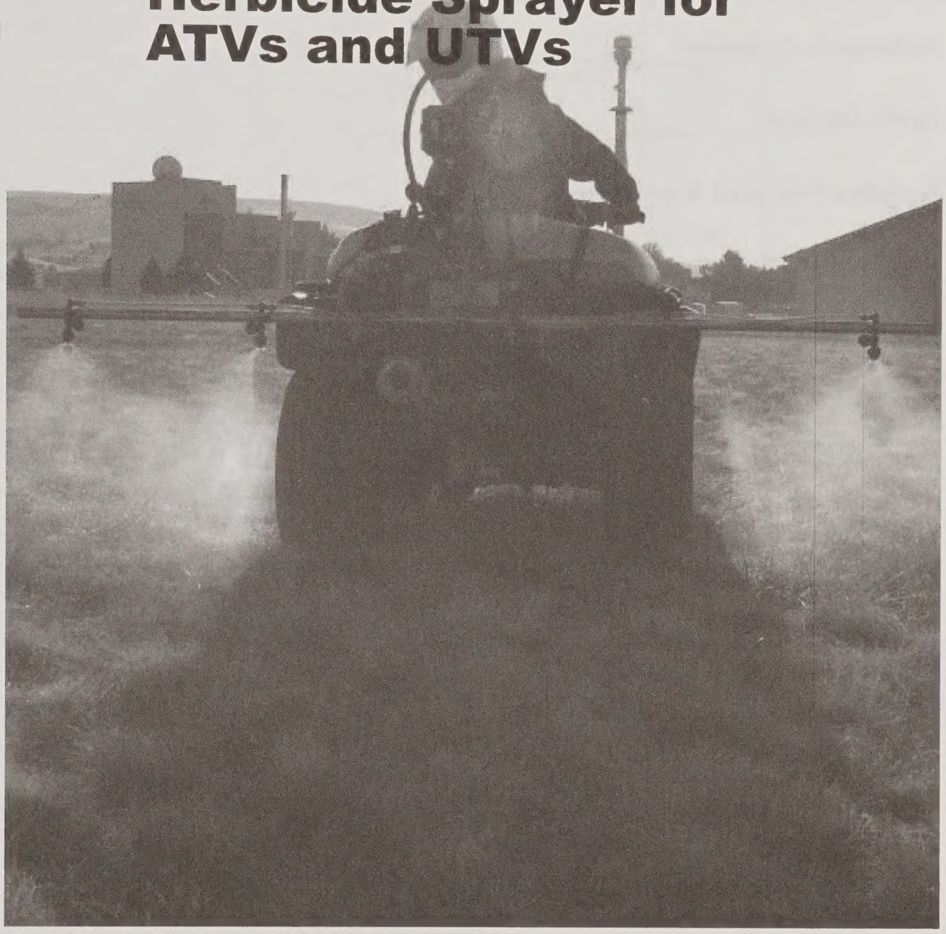


Pesticide Precautionary Statement

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

Field Evaluation of a Constant-Rate Herbicide Sprayer for ATVs and UTVs



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Project Leader

USDA Forest Service
Technology and Development Program
Missoula, MT

6E62D49 Improved Weed Sprayer

April 2008

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Acknowledgments

Special thanks for field input from Brett Glover of the Mountain City Ranger District, Humboldt-Toiyabe National Forest, and Matt Custer from the Hahns Peak-Bears Ears Ranger District, Medicine Bow-Routt National Forests. Thanks to the many behind-the-scene MTDC personnel for their support, with a special thanks to Andy Trent, Dick Karsky, Ian Grob, Bert Lindler, and Ted Cote.

Introduction

All-terrain vehicles (ATVs) and utility vehicles (UTVs) are widely used for spraying herbicides on range and forest lands. Although large agricultural sprayers have technology that allows them to apply herbicides consistently and uniformly, that technology is just beginning to be adapted for ATVs and UTVs. The Missoula Technology and Development Center (MTDC) tested an ATV sprayer that can apply liquid herbicides at a constant rate while the ATV is traveling between 2 and 4½ miles per hour (figure 1). Without this technology, the application rate would vary whenever the ATV speeds up or slows down. Applying herbicide at a constant rate helps reduce the possibility that too much herbicide might be applied, reduces the applicator's exposure to herbicides, and is more effective and economical. The cost of the sprayer, including the tank and boomless nozzle, is about $2,225.

Highlights...

- ATVs are being widely used to apply herbicides.
- MTDC tested a system that allows herbicide to be applied at a constant rate even when the ATV's speed changes.
- Such a system can reduce the possibility that too much herbicide might be applied, reduce the applicator's exposure to herbicides, and is more effective and economical than standard systems used on ATVs.

Figure 1—A constant rate herbicide sprayer on a Honda Foreman ATV. This system can spray a constant 13 gallons per acre while the ATV is traveling between 2 and 4½ miles per hour. This setup used a single 22-foot-wide boomless nozzle.

Application and Equipment Issues

Existing ATV sprayers apply herbicides using a small diaphragm pump that produces a constant pressure, typically 20 to 40 pounds per square inch. For herbicides to be applied at a constant rate (typically given in gallons per acre), the applicator must operate the ATV or UTV at a set speed. Ditches, rocks, loose soil, holes, brush, trees, and steep slopes make it impossible to safely maintain a set speed (figure 2). If an ATV slows to half the intended speed, the amount of herbicide applied can double. It's not economical or desirable—and may be illegal—to apply twice the intended rate of herbicide.

Constant rate sprayers, such as the one being tested by MTDC, automatically vary the pressure to the spray nozzle. As the vehicle goes faster, the pressure and flow to the nozzle increase. As the vehicle slows down, the pressure and flow decrease. A computerized controller, flowmeter, and GPS speed sensor work together to vary the system's pressure by adjusting the speed of the pump.

Constant rate sprayer systems have drawbacks. Computerized controllers add complexity, require more time to calibrate, and are one more piece of equipment that can go wrong. Changing the system pressure alters spray patterns, drift, and droplet size. Improvements in GPS tracking, diaphragm pumps, controllers, and nozzles are reducing or eliminating some of the problems associated with constant rate spray systems.

Figure 2—Slowing an ATV on steep slopes around ditches, rocks, or brush will cause spray application rates to increase with a standard sprayer. A constant rate sprayer automatically varies the pressure to the nozzle when the ATV changes speeds.

Equipment Setup

Test equipment for the 12-volt constant rate sprayer was set up on a Honda Foreman ATV. The system includes a spray tank, control system with console, GPS speed sensor, flowmeter, pump, electronic pump driver, and nozzle. Except for the spray tank, this system could easily be adapted to a UTV. The test included spraying with boom and boomless nozzles to see how well each type of nozzle functioned with the constant rate sprayer.

Spray Tank

The 13-gallon (50-liter) Spray Rider tank is made by C-Dax, a New Zealand company (figure 3). There is only one supplier for C-Dax tanks in the United States and the inventory seems to be limited at times. This tank is designed with a low profile. Other low-cost spray tanks are available, but they may exceed the weight capacity of an ATV's rack and will raise the ATV's center of gravity. The lower the center of gravity, the less chance that an ATV might roll in steep terrain. A 21-gallon (80-liter) tank is available from C-Dax. If a larger tank is needed, a 24.5-gallon tank is available from Warne Chemical and Equipment Co.

Figure 3—The low profile of this 13-gallon (50-liter) Spray Rider tank from C-Dax helps keep the center of gravity low, reducing the chance that the ATV might roll.

Control System

Flow rates through the nozzles are controlled with the Spray-Mate II, manufactured by Micro-Trak Systems, Inc. The Spray-Mate II is reasonably priced, has a flowmeter range of 0.5 to 5 gallons per minute, and a console that is easy to use. The controller kit includes a console, flowmeter, Astro II GPS speed sensor manufactured by Garmin, electronic pump driver, and complete wiring harness.

Although most constant rate systems use a servo valve to restrict flow, the Spray-Mate II uses an electronic pump driver to control the speed of the diaphragm pump, varying the pump pressure and the flow. Signals from the GPS and flowmeter feed information to the console, which controls the pump speed through the electronic pump driver (figure 4).

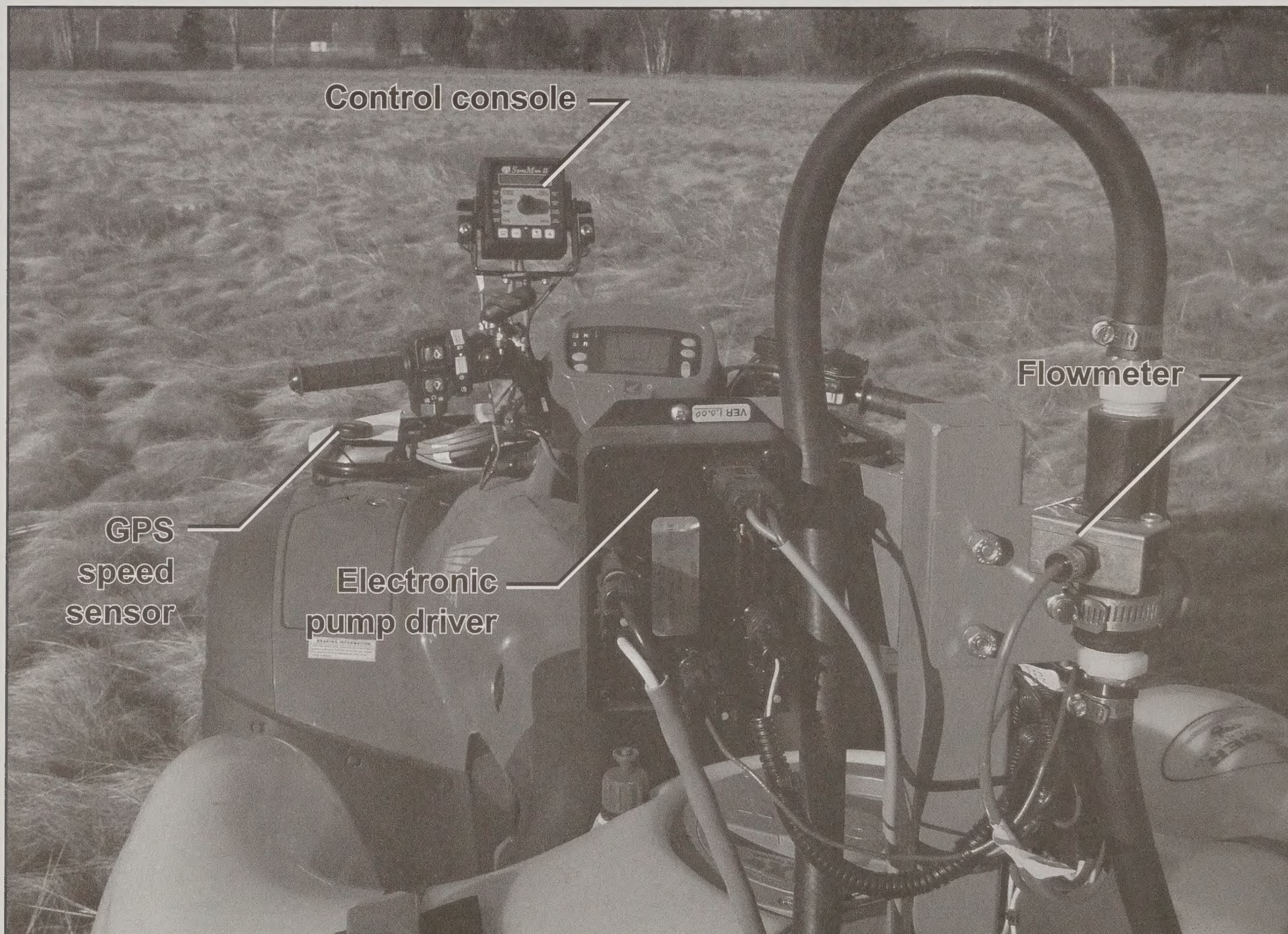

Figure 4—A flowmeter and GPS speed sensor feed information to the Spray-Mate II control console. A signal from the console controls the pump's speed through the electronic pump driver, maintaining a constant application rate even when the ATV speeds up or slows down.

Console

The Spray-Mate II console records the number of acres sprayed, application rate, ground speed, distance traveled, and total volume applied (figure 5). The console is relatively small and easy to mount out of the way on the ATV handlebars. The console can control up to three separate boom solenoids. The applicator uses a single selector switch and four pushbuttons to input all calibration numbers, select the desired output data, reset the console, and select auto or manual modes.

Calibration and output units can be displayed in the English or metric system. The liquid crystal display is relatively easy to see in direct sunlight, but a visor over the display would be a nice addition. The manual does a good job of covering all the procedures in the proper order, but the task of entering the initial calibration information is slow and tedious.

Figure 5—The control system console on the Spray-Mate II displays the herbicide application rate using information from the flowmeter and GPS speed sensors. Other functions that can be displayed include speed, distance, acres sprayed, and volume sprayed.

Speed Sensor

The Spray-Mate II's GPS speed sensor functions very well and is much simpler to set up than magnetic or radar sensors. GPS sensors are more reliable than radar sensors, which have trouble sensing speed on rough terrain or in vegetation. The GPS sensor also eliminates concerns that magnetic sensors might fail to record the true speed of the ATV, particularly if the wheels slip and the ATV doesn't move as far as the sensors indicate. Speed calibration numbers supplied by the manufacturer were accurate to within 1.5 feet in 1,000 feet of travel.

The Astro II GPS (figure 6) takes about 5 minutes to acquire a satellite fix in a new location. Small LED lights indicate power to the unit and the status of the GPS signal. The GPS has not been tested under a dense forest canopy. Micro-Trak offers a more powerful GPS receiver, the Astro 5.

Figure 6—The Astro II GPS sends a signal to the control system console as it traces the speed of the ATV. LED lights indicate power to the unit and the status of the GPS signal.

Pump

Small 12-volt diaphragm pumps used in ATV sprayers must be chosen carefully. The original pump included with the spray tank, rated at 1.2 gallons per minute at 60 pounds per square inch, struggled to produce enough flow for the boomless nozzle. We replaced the pump with a SHURflo 2088 pump rated at 3.6 gallons per minute at 25 pounds per square inch and mounted it outside the enclosure on the tank to keep the pump from getting hot (figure 7).

Reducing the speed of the pump with the Micro-Trak electric pump driver will not hurt the pump, according to a technician at SHURflo. The pump performed well in our spray tests. Pumps should have Viton valves and Viton or Santoprene diaphragms for herbicide applications.

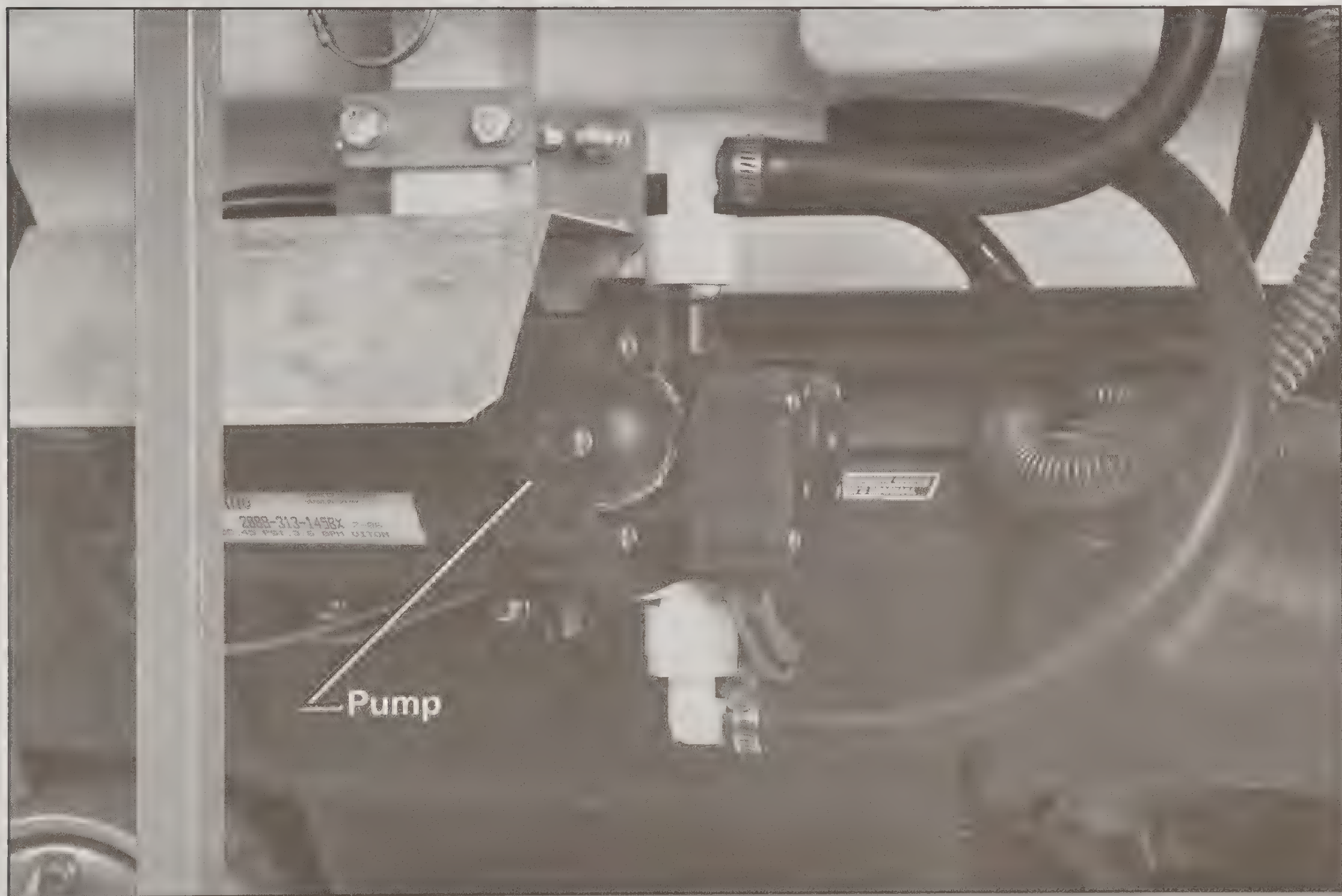

Figure 7—The SHURflo 2088 12-volt diaphragm pump is rated at 3.6 gallons per minute at 25 pounds per square inch.

Nozzles

Boomless nozzles are becoming more popular than boom-mounted nozzles because they cover more ground with fewer passes and are less prone to damage during range and forest spraying. The spray coverage and droplet consistency of boomless nozzles are typically not as uniform as nozzles mounted on booms. Improvements in boomless nozzle technology, such as in the Boominator 1400FM, produce decent spray patterns and droplet sizes at pressures between 20 and 40 pounds per square inch (figure 8). The nozzle was mounted at a 45-degree angle to the ground to help keep the spray off the ATV and the applicator.

The Turbo TeeJet TT11002 boom fan nozzles from Spraying Systems (figure 9) are rated for a wide range of pressures (15 to 60 pounds per square inch), have a 110-degree spray angle, and are designed to reduce drift. During testing, the boom was configured with five nozzles that sprayed a 100-inch swath.

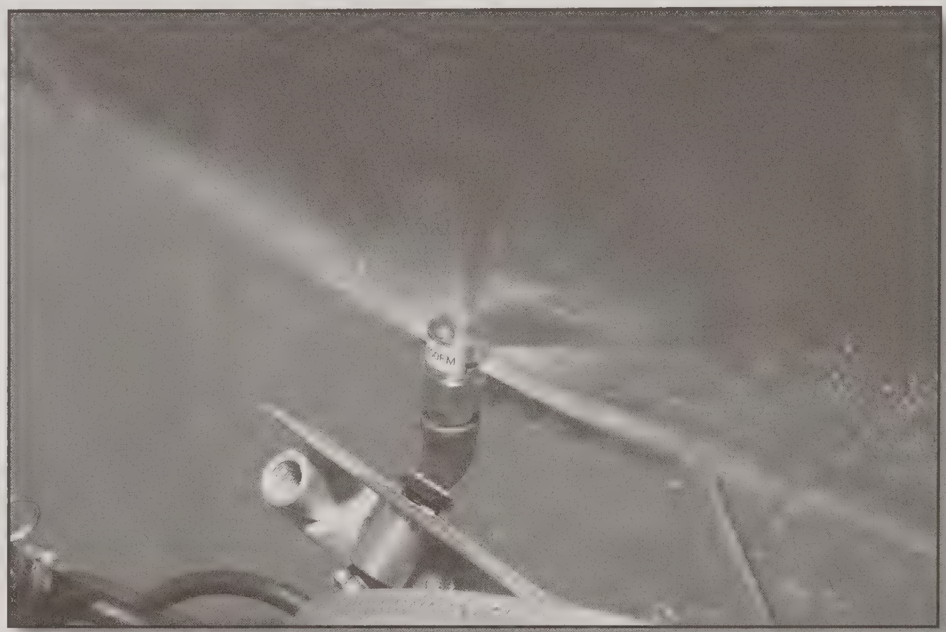

Figure 8—The Boominator 1400FM boomless nozzle created a relatively consistent droplet pattern over a 20- to 22-foot swath.

Figure 9—Boom-type nozzles produce uniform spray patterns over a wide range of pressures. Booms aren't always suitable for rough terrain and brush in many range and forest settings.

Constant Rate Testing

The relationship between speed, pressure, flow rate, and spray width was observed for both boom and boomless nozzles during testing. These tests showed the typical range of the constant-rate sprayer and the effect of ATV speed changes on nozzle spray patterns, droplet size, and application rates. More extensive testing could be done to look at other speed ranges, application rates, and boom or boomless configurations.

While travel speed varied from 2 to 6 miles per hour during the boom nozzle test, the flow rate varied by no more than 1.9 gallons per acre when the flow rate was set to 20 gallons per acre (table 1). At speeds of 3 to 5 miles per hour, the flow rate was a constant 20 gallons per acre.

Table 1—Test results using five Turbo TeeJets TT11002 boom nozzles 20 inches apart and 20 inches from the ground with the flow control set at 20 gallons per acre (gpa).

Speed (mi/h)	Pressure (psi)	Flow (gpa)	Spray Width (ft)
2	8	21.9	9.3
3	18	20.0	9.3
4	32	20.0	9.2
5	49	20.0	9.2
6	58	18.2	9.2

While travel speed varied from 2 to 5 miles per hour during the test of the boomless nozzle, the application rate varied by no more than 3 gallons per acre when the flow rate was set to 13 gallons per acre (table 2).

Table 2—Test results using a Boominator 1400FM boomless nozzle mounted 36 inches above the ground with the flow control set at 13 gallons per acre.

Speed (mi/h)	Pressure (psi)	Flow (gal/acre)	Spray Width (ft)
2.0	13	13	16.0
3.0	25	13	20.5
4.0	38	13	22.0
4.5	38	11	22.0
5.0	38	10	22.0

During tests of both the boom and boomless nozzles, the pressure required to maintain a constant flow at 2 miles per hour was less than the manufacturers' recommendations, but it was still enough to produce a reasonable spray pattern. A conventional sprayer with constant pressure calibrated at 4 miles per hour could have had a flow rate closer to 30 gallons per acre at 2 miles per hour and 12 gallons per acre at 5 miles per hour.

Test results show that the pressure to the boomless nozzle peaks at 38 pounds per square inch, so as the speed increases, the application rate begins to drop off. A narrower spray width would help eliminate this problem because the smaller diaphragm pumps used on ATVs don't have the capacity to maintain the application rate over such a wide swath. The flowmeter's accuracy was verified before performing the constant rate test.

Herbicides can only be applied at a constant rate if the applicator does a perfect job of spacing the distance between spray swaths. This becomes more difficult with a boomless sprayer. Because the swaths are relatively wide, it is difficult to see tire tracks or dye markings from previous swaths. At slower speeds, the spray width decreases for a boomless nozzle because pressure drops.

Distribution and Drift Testing

Distribution and drift testing was performed on a test grid. A 5-percent red food dye solution was sprayed on white test cards 6 inches above the ground. The cards were 2 ½ feet apart for 15 feet on either side of the centerline (figure 10). Testing was conducted when the wind speed was less than 4 miles per hour, so wind drift was minimal. The cards were scanned using REMSpC Stainalysis program. This test gave a general overview of the difference between a boom and a boomless nozzle at two different speeds. More extensive testing of ATV spray nozzles would be beneficial because the technology continues to change rapidly.

Figure 11 shows the REMSpC Stainalysis program's results of testing with a boom and a boomless nozzle when the ATV was driven at 4 1/2 miles per hour. Figure 12 shows the REMSpC Stainalysis program's results of testing with the five-nozzle boom at 2 ½ and 4½ miles per hour. Figure 13 shows the results of testing with the boomless nozzle tested at 4½ miles per hour.

Figure 10—A 5-percent red food dye solution was sprayed on white test cards during distribution and drift testing. The ATV sprayed the dye solution perpendicular to the line of test cards using either the boom or boomless nozzles at speeds of 2 ½ and 4 ½ miles per hour. The inset shows the spray droplet pattern on a test card.

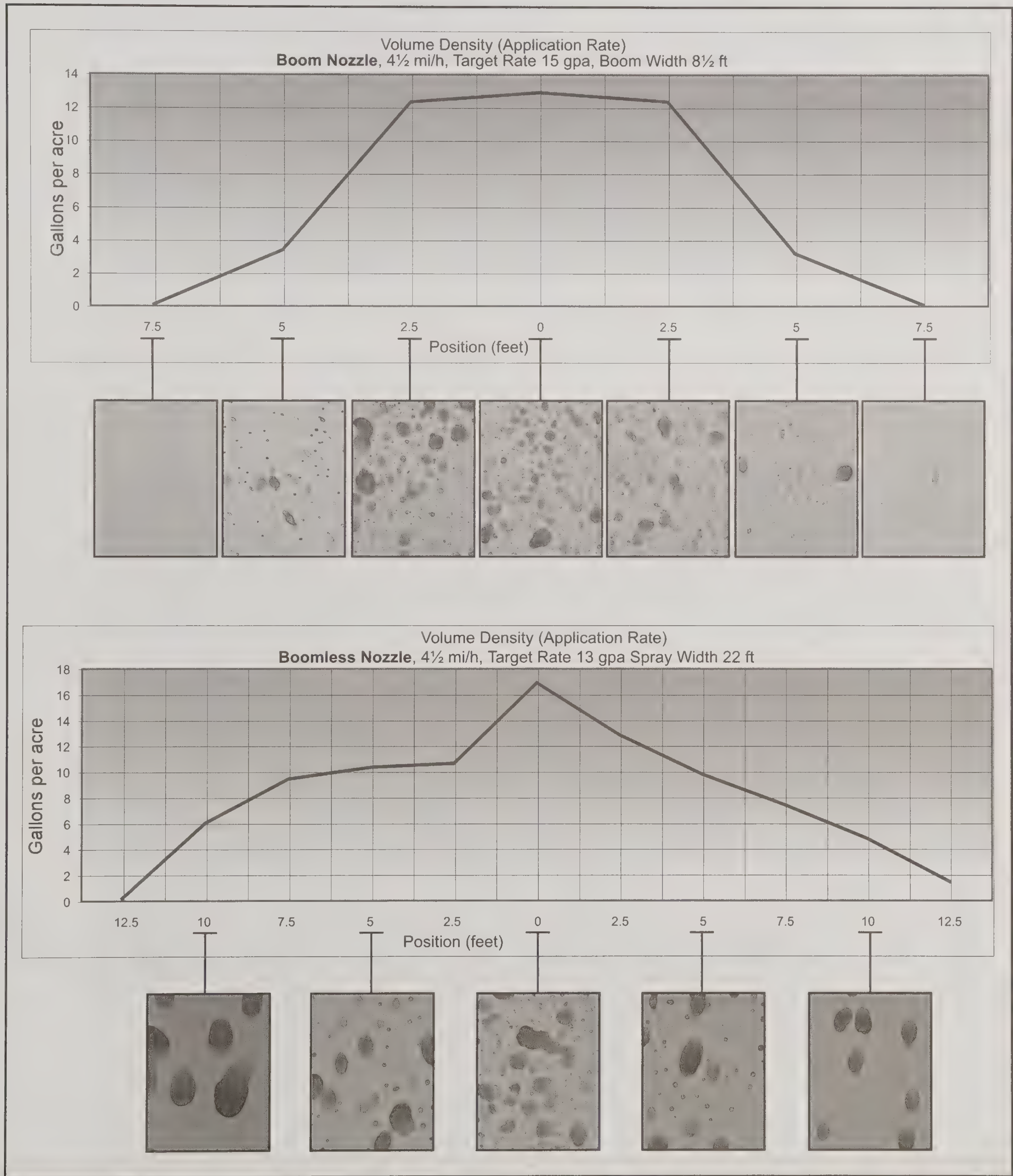

Figure 11—Results from the REMSpC Stainalysis program show a volume density graph and a the spray droplets on small section of the card used in the analysis for both the boom and boomless nozzles at 4½ miles per hour.

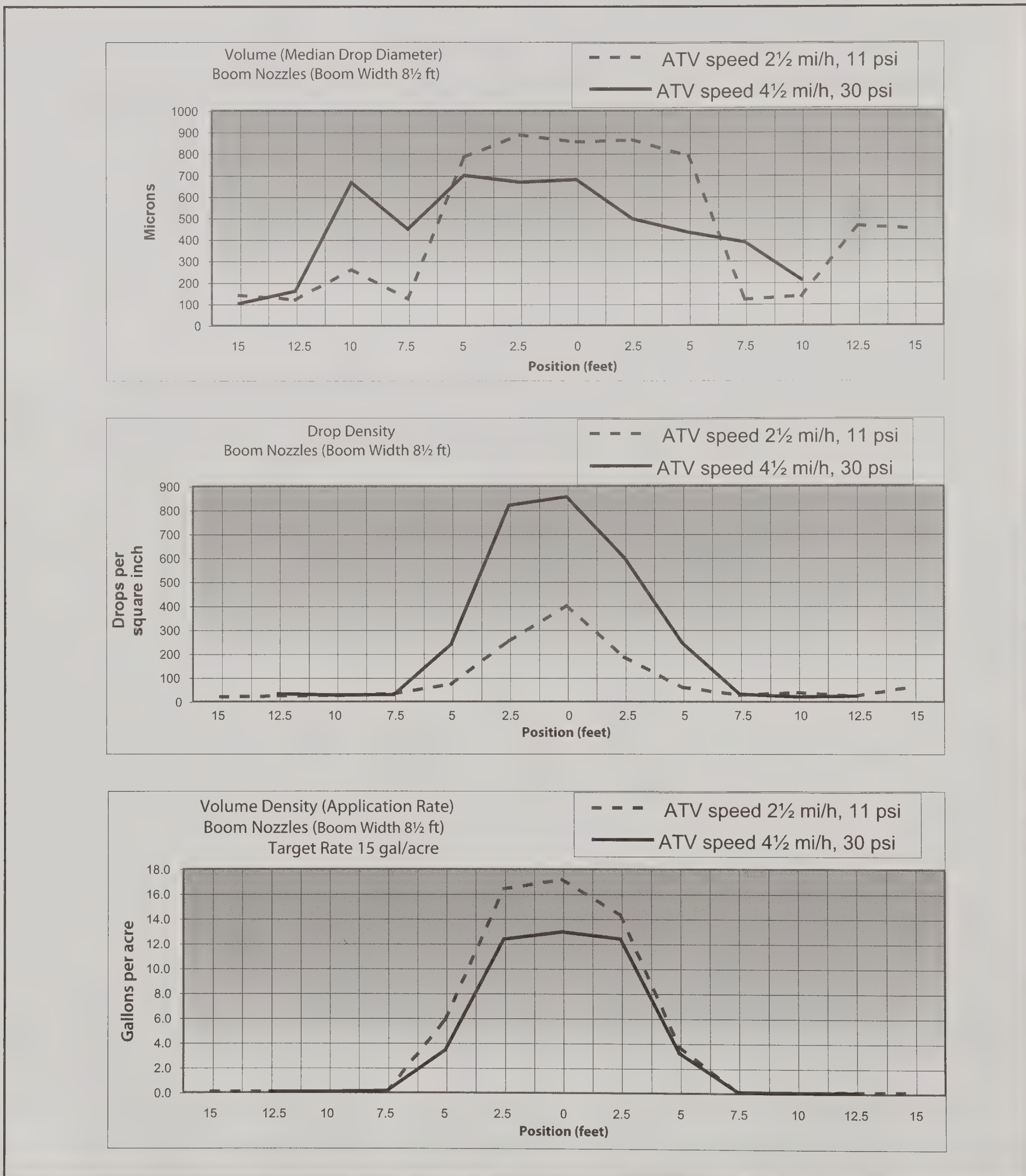

Figure 12—Results from the REMSpC Stainalyis program for the boom nozzle distribution test show the volume median drop diameter, drop density, and volume density at 2½ and 4½ mph. The boom has five flat fan nozzles (TurboTeeJet TT110002) that are 20 inches from the ground and spaced 20 inches apart.

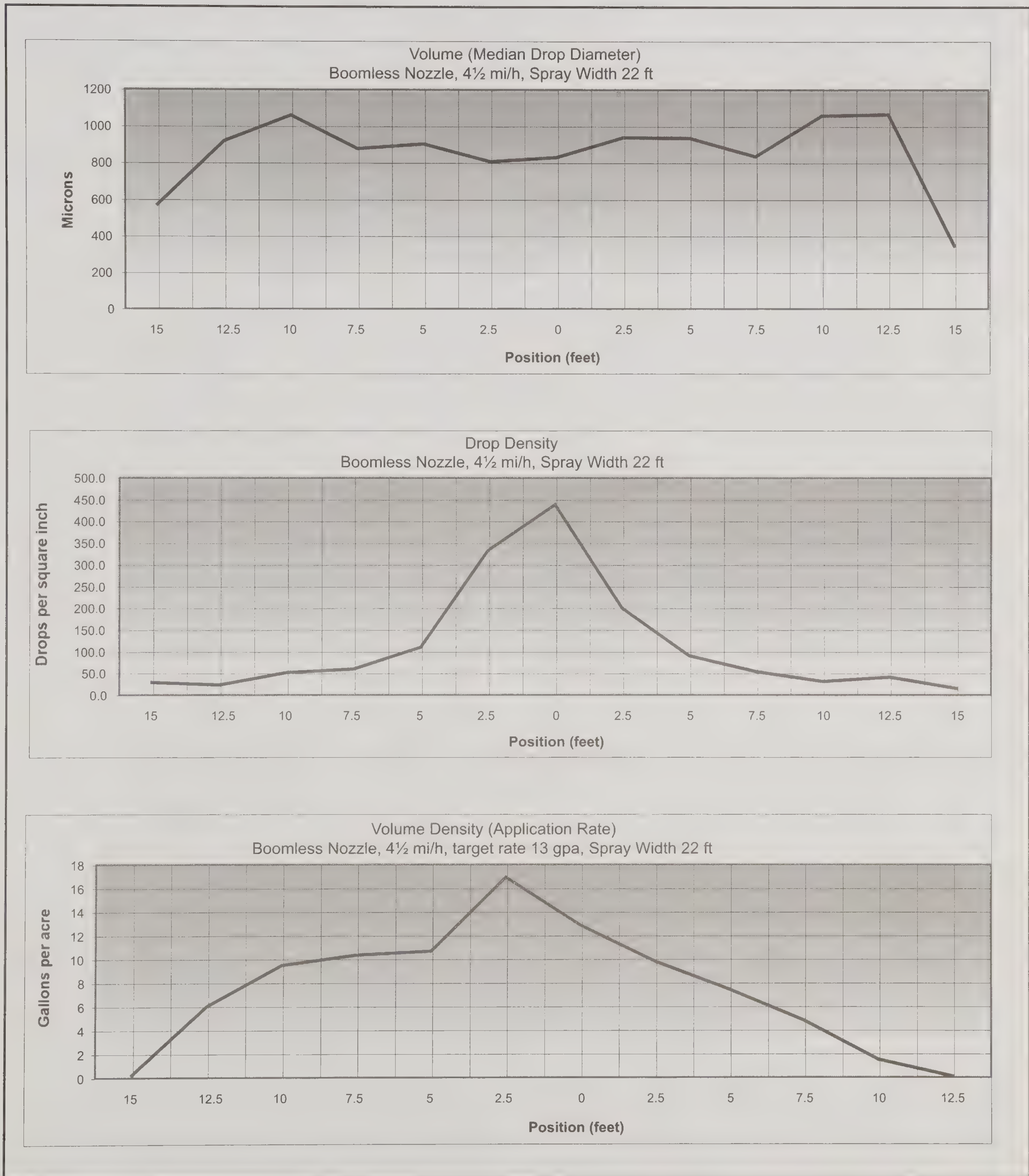

Figure 13—Results from the REMSpC Stainalysis program for the boomless nozzle distribution test show the volume median drop diameter, drop density, and volume density in gallons per acre (gpa) at 4½ miles per hour. The single boomless nozzle (Boominator 1400FM) has a 22-foot spray pattern and was mounted 36 inches from off the ground at a 45-degree angle to the ground.

Calibration Recommendations

The flowmeter's calibration should be checked at the beginning of each spray season. Follow the instructions in the controller manual to check and fine tune the flowmeter's calibration. The GPS system should not need to be calibrated for speed and distance after the system has been initially installed.

Once the flowmeter and GPS have been fine tuned, no other calibration should be required. MTDC calibrated the ATV sprayer on a 1/8-acre (5,445-square feet) test grid using the method described in appendix A.

A quick application rate test was run using the Boominator boomless nozzle (table 3). The sprayer maintained a nearly constant rate of application in gallons per acre. At 2½ miles per hour the applied rate was 13.06 gallons per acre; at 4 miles per hour the applied rate was 13.25 gallons per acre.

Table 3—A quick calibration test shows the application rate for two speeds. The applied rate varies by 0.2 gallons per acre or about 1.5 percent.

Run number	Speed (miles per hour)	Application rate (gallons per acre)
1	2.5	13.1
2	4.0	13.3

Discussion

When purchasing components for a constant-rate sprayer, it is important to select a pump that can produce the pressure and flows required for the number and type of nozzles you will be using. Some pressure will be lost from fittings and hoses. The typical hose and fittings from the pump should be ½ inch in diameter. Branches to individual nozzles should be ⅜ inch in diameter.

A good fluid flow calculator can be found at: *http://www.gates.com/industrial/pressure/fluidflow.cfm?location_id=3044*. A pressure loss of 5 pounds per square inch through hoses and fittings would be too much. Don't try to get by with a pump that barely meets the minimum requirements.

Try to maintain the manufacturer's recommended nozzle pressures to ensure the spray has droplets of the right size and produces the proper patterns.

Before heading to the field, find the optimal application rate by calibrating the system with water. Make sure the application rate is within the herbicide label's recommendations.

Herbicides with higher application rates will require a narrower spray swath because today's 12-volt diaphragm pumps don't deliver the flows required for wider swaths. Powdered herbicides would not work well with this system because the SHURflo 2008 pump does not have enough flow to agitate the tank's contents and the flowmeter would plug too easily.

The Spray-Mate II GPS speed sensor and electric pump driver are easy to install, although the instructions for wiring these components were a little vague. The wiring harness is long and was difficult to tuck out of the way on the ATV. When purchasing the Spray-Mate II controller, work with a Micro-Trak distributor and have them package the controller with the GPS speed sensor, Model FM 500 flowmeter and electronic pump driver.

Programming the Spray-Mate II console was not especially difficult, instructions were clear, and changes were easy to make in the field. The calibration numbers for the Spray-Mate II's flowmeter and GPS sensor were correct and didn't require any fine tuning. It does take some time to find the application rate that will stay locked in at the high and low ends of the speed range. Once this rate is known for a given nozzle configuration and pump, the flow rate readout on the controller locks in quickly and does not fluctuate much as the applicator changes the speed of the ATV.

Equipment Costs and Vendor Data

ATV Spray Rider SR50 Tank by C-dax ($467 each)
Shearer Sprayers, Inc., Dept. ATV
John Shearer
2020 Lampert St.
The Dalles, OR 97058
Phone: 541–296–5784
Web: *http://www.cdax.co.nz/efx/include/common/dealers/dealers2.asp?country=USA&town=Oregon*

"Jack Rabbit" ATV Spray Tank ($700 to $1,000 each)
Warne Chemical and Equipment Co.
2680 Commerce Rd.
Rapid City, SD 57702
Phone: 1–800–658–5456
Web: *http://www.warnechemical.com/Jack%20Rabbit_1.htm*

Spray-Mate II Controller ($1,351 each)
Micro-Trak Systems, Inc.
P.O. Box 99
Eagle Lake, MN 56024
Phone: 507–257–3600
Web: *http://www.micro-trak.com*
Note: The Web site has an excellent locator to find the nearest dealer.

SHURflo 2088-313-145 Spray Pump ($131 each)
SHURflo, LLC
5900 Katella Ave.
Cypress, CA 90630
Phone: 562–795–5200 or 800–854–3218
Web: *http://www.shurflo.com*
Note: The pump was purchased from Dultmeier Sales.

Boominator 1400FM Spray Nozzle, boomless ($135 each)
Rittenhouse
Phone: 1–800–461–1041
Web: *http://www.rittenhouse.ca*
or
KLM Supply, Inc.
7307 Vista Ridge Lane
Sachse, TX 75048
Phone: 214–850–0682
Web: *http://www.klmsupplyinc.com*

TeeJet Spray Nozzles, dry boom (Turbo TT11002 $3 each, XR11002 $4.25 each)
TeeJet, division of Spraying Systems Co.
P.O. Box 7900
Wheaton, IL 60189–7900
Phone: 630–662–5000
Web: *http://www.teejet.com*
Note: These nozzles were purchased from Dultmeier Sales.

Fittings, hose, gauge, valves, couplings, control valve ($150)
Dultmeier Sales
Phone: 1–800–228–9666
Web: *http://www.dultmeier.com*

Stainalysis freeware
REMSpC Spray Consulting
Web: *http://www.remspc.com/Stainalysis/*

Appendix A—Calibration of a Constant Rate Sprayer Using a ⅛-Acre Test Grid

Calibrating a constant rate sprayer that varies pressure can be more complicated than calibrating a system with a set pressure. The constant rate sprayer won't turn the boom on until the ATV is traveling fast enough for the selected application rate. The Spray-Mate II controller includes a test speed function for performing stationary calibration, but we wanted to ensure the computer was functioning correctly. You can calibrate the sprayer using the following procedure.

Fill the sprayer tank with clean water. Enter the boom width and target rate into the controller. The boom width is the number of nozzles on the boom times the nozzle spacing in inches. Follow the nozzle manufacturer's recommendation for nozzle spacing and distance from the ground. The target rate is the desired application rate. The target rate should be within the recommended application rate listed on the herbicide label. Use the nozzle manufacturer's data to calculate the approximate rate the sprayer can apply.

The sprayer's output is limited by the flow and pressure of the pump. Remember, the flow and pressure listed by the pump manufacturer do not include line losses. The pressure and flow at the nozzle will be somewhat less than shown on the pump label.

Set the controller in automatic mode and the selector switch to the target rate position. Turn on the sprayer while traveling within the desired travel speed (typically 2 to 4 miles per hour) to verify that the system can apply the target rate. If the system can apply water at the target rate at the low end of the speed range, but can't at the high end, set a lower target rate. If the system can apply the target rate at the upper end of the speed range, but not at the lower end, set a higher target rate.

After adjusting the desired target rate, verify that the controller can lock onto this number at both ends of the speed range. An application rate within 10 percent of the desired target rate is probably acceptable at the upper or lower ends of the speed range. If the target rate is not within label requirements, the speed range or nozzle configuration needs to be changed.

Measure the width of the spray swath in feet while spraying at the target rate. The width should be close to that specified by the nozzle manufacturer.

Lay out a ⅛-acre test plot (5,445 square feet). Divide 5,445 by the width of the spray swath to calculate the distance that must be traveled to cover ⅛ acre.

As an example: The Boominator 1400FM boomless nozzle has a spray swath of 22 feet. To cover ⅛ acre, the sprayer must travel a distance of 5,445/22 feet = 247.5 feet.

Mark the beginning and end of the travel distance, in our case 247.5 ft.

Securely attach a bucket under one spray nozzle and make sure all the nozzle's flow will be directed into the bucket.

While traveling within the desired speed range, turn on the spray boom at the beginning marker. Turn the boom off as you pass the end marker.

Determine the gallons of liquid in the bucket using a liquid measuring container or by weighing the water in pounds and dividing by 8.33 to convert the pounds of water to gallons. Don't forget to subtract the weight of the bucket.

To calculate the gallons per acre, multiply the gallons collected in ⅛ acre by the number of nozzles times eight.

When you are using more than one nozzle, it is a good practice to verify that the volume sprayed from each nozzle is within 5 percent of the volume sprayed from other nozzles.

About the Author

Gary Kees is a project leader specializing in reforestation and nurseries, facilities, and GPS projects at MTDC. He received his bachelor's degree in mechanical engineering from the University of Idaho. Before coming to MTDC in 2002, Gary worked for the Monsanto Co. in Soda Springs, ID, as a mechanical/structural engineer and project manager.

Library Card

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All-terrain vehicles (ATVs) and the larger utility vehicles (UTVs) are widely used for spraying herbicides on range and forest lands. The Missoula Technology and Development Center modified and tested an ATV sprayer that can apply liquid herbicides at a constant rate, even when the ATV's speed varies from 2 1/2 to 4 1/2 miles per hour. Without this technology, the application rate would vary whenever the applicator sped up or slowed down. Applying herbicide at a constant rate helps prevent the possibility that too much herbicide might be applied, reduces the applicator's exposure to herbicides, and is more effective and economical.

Keywords: all-terrain vehicles, equipment, herbicides, pesticides, utility vehicles

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Additional single copies of this document may be ordered from:

USDA Forest Service
Missoula Technology and Development Center
5785 Hwy. 10 West
Missoula, MT 59808–9361
Phone: 406–329–3978
Fax: 406–329–3719
E-mail: *wo_mtdc_pubs@fs.fed.us*

For additional information about herbicide sprayers, contact Gary Kees at MTDC:

Phone: 406–829–6753
Fax: 406–329–3719
E-mail: *gkees@fs.fed.us*

Electronic copies of MTDC's documents are available on the Internet at:

http://www.fs.fed.us/eng/t-d.php

Forest Service and Bureau of Land Management employees can search a more complete collection of MTDC's documents, CDs, DVDs, and videos on their internal computer networks at:

http://fsweb.mtdc.wo.fs.fed.us/search/